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(54) **Electrically insulating polymer matrix with conductive path formed in situ.**

(57) An electrical component is made from an electrically insulating polymer matrix (27) filled with electrically insulating fibrous filler (34) which is capable of heat conversion to electrically conducting fibrous filler (32) and has at least one continuous electrically-conductive path formed in the matrix by the in situ heat conversion of the electrically insulating fibrous filler. In a preferred embodiment, the fibrous filler is thermally stabilized polyacrylonitrile fibers, and the conductive path is formed by in situ heat-converted thermally-stabilized polyacrylonitrile fibers which have been converted by directing a laser beam through a mask having a predetermined pattern to melt the polymer and to convert the thermally-stabilized polyacrylonitrile fibers into their conductive form.

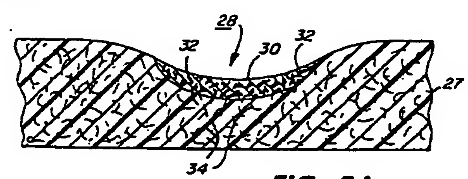

FIG. 5A

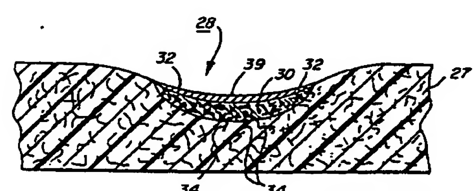

FIG. 5B

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Description

The present invention relates generally to electrical components, methods for making electrical components and machines employing such electrical components. In particular, it relates to multifunctional electrical components with both electrical and mechanical structural functionality and in particular is directed to the use of such components in automatic reproducing machines such as office copiers, duplicators and printers. More specifically, the component comprises an electrically insulating polymer matrix which is filled with an electrically insulating fibrous filler capable of heat conversion to an electrically conducting fibrous filler where at least one continuous electrically conductive path is formed by the in situ heat conversion of the electrically insulating fibrous filler.

In electrostatographic reproducing apparatus commonly used today a photoconductive insulating member is typically charged to a uniform potential and thereafter exposed to a light image of an original document to be reproduced. The exposure discharges the photoconductive insulating surface in exposed or background areas and creates an electrostatic latent image on the member which corresponds to the image on the original document. Alternatively, a light beam may be modulated and used to discharge portions of the charged photoconductive surface selectively to record the desired information thereon. Typically, such a system employs a laser beam. Subsequently, the electrostatic latent image on the photoconductive insulating surface is made visible by developing the image with developer powder, referred to in the art as 'toner'. Most development systems employ developer which comprises both charged carrier particles and charged toner particles which triboëlectrically adhere to the carrier particles. During development the toner particles are attracted from the carrier particles by the charged pattern of the image areas of the photoconductive insulating area to form a powder image on the photoconductive area. This toner image may be subsequently transferred to a support surface such as copy paper to which it may be permanently affixed by heating and/or by the application of pressure.

In commercial applications of such products it is necessary to distribute power and/or logic signals to various sites within the machine. Traditionally, this has taken the form of utilizing conventional wires and wiring harnesses in each machine to distribute power and logic signals to the various functional elements in an automated machine. While the conventional approach has been immensely effective in providing convenience products, with increasing demands on manufacturing cost and the desire for automated assembly, different approaches have to be provided. For example, since individual wires and wiring harnesses are inherently very flexible, they do not lend themselves to automated assembly such as with the use of robotics. Furthermore, such harnesses may have to be handled or moved several times to make all connections required. This is a highly labor-intensive process frequently requiring routing of several harnesses through channels around component elements manually with the final connection being also accomplished manually thereby resulting in potential human error in the assembly. The potential for human error is reduced with the use of automated and in particular robotic assembly. However, robots are incapable of or inefficient in handling wire harnesses because the wires and cables vary in position because of their flexibility. In addition to the relatively high labor costs associated with harness construction and installation, electrical wiring harnesses as well as their connectors are less than totally reliable in use. Furthermore, and with increasing sophistication of the capabilities of such products, a plurality of wiring harnesses may be required in any individual machine which can require a large volume of space thereby increasing the overall size of the machine. Accordingly, there is a desire to provide an alternative to the conventional wiring and wiring harnesses that overcomes these difficulties.

Several techniques have been proposed to overcome these difficulties, including techniques wherein three-dimensional features are molded into a chassis or casing with the potential to build circuitry into the chassis, subchassis or other part. Briefly, the aforementioned techniques can be categorized as utilizing dry processes or wet processes. Examples of dry techniques are the Konec process developed by Union Carbide, and the Adap process developed by Allied Signal. Both processes involve a thermal transfer or embossment of either a conductive ink or metallic particles into an injection-molded substrate. Another example of a dry process is the film-in-mold decorating technique, where in a film having a metallized pattern on it is forced to conform to the interior of a mold and is bonded to the molded part. While capable of use for simple circuitry patterns, they are limited in their abilities to produce fully three-dimensional conductive features. The wet processes can be described generally as semi-additive or fully-additive, with the latter being capable of providing selective metallization of planar and nonplanar three-dimensional features on multiple surfaces of complex form. In the semi-additive processes, thermoplastic substrates are chemically pretreated to provide anchoring sites for subsequent catalyst absorption and metallization. Following the surface adhesion promotion treatment, the molded substrate is processed through a catalyst solution followed by electroless plating of a thin copper layer. Thereafter, resist application and image formation, followed by copper electroplating and removal of the temporary resist, are accomplished.

In addition, there are two fully-additive techniques which permit selective plating on three-dimensional surfaces. In the Photoselective Plating process developed by PCK Technlogy Division of Kollomorgen Corporation, a photo-imaginable plating catalyst is used to form three-dimensional images by selectively exposing catalyzed surfaces through a mask to ultraviolet light which initiates a photochemical reaction that

converts the catalyst into metallic images corresponding to the desired circuit pattern. Thereafter, copper is applied to the circuit pattern in an electroless bath. The second additive technique is the Mold-n-Plate process also developed by PCK Technology Division wherein two different resin systems are used. One resin contains a plating additive while the second remains plating neutral. This involves a two-stage molding process wherein the first molding is with the resin containing the catalytic plating additive in a mold having the circuit design desired. This is followed by a second injection molding technique with the non-catalytic resin which covers areas of the molded part which are not part of the circuit and permits the circuit design to be exposed on the surface. Thereafter, copper plate is applied to the exposed circuit pattern made up of the resin containing the plating catalyst.

It has also been previously proposed (US-A-4,286,250) to create electroconductive pathways in electrically insulating polymers, such as polyimides such as Kapton available from E. I. DuPont Company, by exposing them to radiation from a laser to pyrolyze the polymer. While capable of providing a electro-conductive pathway, these pathways tend to be extremely delicate and subject to damage upon minimal handling. This is caused by the particulate nature of the conducting region that is only minimally adhered to the pathway resulting from the outgasing accompanying laser pyrolysis which disrupts the mechanical structure of the polymer.

US-A- 3,056,881 forms a metal conductive trace in a work piece by exposing the surface to radiant energy, such as an electron beam, which reduces the normally non-conductive metal oxide such as alumina to pure aluminum which becomes the conductive portion of the device. Either the electron beam can be moved to trace a pattern on the work piece or the work piece itself moved relative to the beam.

US-A- 3,627,858 describes a method for performing a design on the surface of a thermoplastic article using laser radiation to produce an embossed surface. A mask may be interposed between the laser and the article to project the radiation from the laser in a predetermined pattern on the article.

US-A- 4,159,414 is directed to forming electrically-conductive paths on three-dimensional substrates by exposing a polymer composition containing a metal compound, preferably a metal oxide, to a high-intensity laser beam to reduce the metal compound to its elemental state thereby providing an electrically conductive path.

US-A- 4,286,250 is directed to laser-formed resistor elements wherein an insulator substrate has heat applied, for example, by directing a laser beam to a predetermined portion to provide a carbonized conductive resistor portion.

US-A- 4,568,632 is directed to using a mask when laser etching a polyimide substrate.

IBM Technical Disclosure Bulletin Vol. 9, No. 11, April 1967, Page 1474 entitled "Metal Plating of Pyrolyzsate Circuitry", to T. F. Saunders et al. is directed to fabricating printed circuits by the radiant energy pyrolyzation of an organic polymer coating on a substrate to produce a conductive carbonaceous pattern which is subsequently sensitized and immersed in an electroless copper plating bath to provide a copper film on the conductive pattern. The film thickness can be increased by electroplating.

DE-B- 2,647,796 is directed to a circuit board designed as the bottom of a casing which is produced by injection molding thermoplastic material so that the molded section has channels on the side for the printed wiring. The thermoplastic material is then activated and rendered electrically conductive and provided with a coating of a conductive material that forms the wiring paths in an electroplating bath. The process permits a high degree of automation, a three-dimensional profile and the elimination of wiring operations.

The present invention is directed to an electrical component which is as claimed in the respective appended claims.

In one aspect of the present invention, the component is a multifunctional component providing both an electrically-conductive pathway and a mechanical structure.

The present invention will now be described by way of example with reference to the accompanying drawings, in which:

Figure 1 is an isometric view partially exploded with a portion of the frame section of an electrostatographic reproducing apparatus with a representative illustration of a wiring harness conventionally employed;

Figure 2 is a view similar to that illustrated in Figure 1 wherein the conventional wiring harness has at least in part been replaced by the electric conductor of the present invention;

Figure 3 is schematic illustration of a system for forming the electrically-conductive traces in a structural member;

Figures 4A and 4B are cross-sectional views of a three-dimensional structural member of the invention having one electrically conductive path formed therein, and

Figures 5A and 5B are enlarged views of the electrically conductive paths in Figure 4.

Referring now to a comparison of Figures 1 and 2, the significance of the present invention will be immediately appreciated. In each of these figures only a structural frame 10 together with machine drive module 12, and platen drive module 14 are illustrated as parts of an electrostatographic reproducing apparatus. For a further description of the machine elements and its manner of operation, attention is directed to US-A-4,563,078. In Figure 1, a conventional wiring harness is illustrated comprising a plurality of individual wires 16 held in the harness configuration by fasteners 18, the harness serving to distribute power and/or logic signals from, for example, the control panel on frame 10 to the main machine drive 12. It will of course be understood that in a completed assembly, there will be a plurality of such wiring harnesses required which,

during assembly of the final product, have to be manually placed in position and connected to the appropriate electrical components. By contrast, Figure 2 illustrates an application of the present invention wherein electro-conductive paths or traces 20 may be formed directly in the machine support frame 10. These electro-conductive paths may be formed as the final step in the manufacture of the individual support frames 20 prior to the assembly of the whole machine, and thereby avoid the necessity for manual placement and connection of the conventional wiring harness.

The electrically insulating polymer matrix may be formed from any suitable host polymer which is electrically insulating. The polymer may be selected from a wide range of commercially-available materials which are suitable for molding or other shaping methods such as, for example, casting, extrusion, pultrusion and transfer molding. Polymers which are hydrophobic, exhibiting low moisture uptake, are preferred because of their more stable volume resistivity at high relative humidity. Naturally, polymers which are non-toxic and have non-toxic thermal decomposition products are preferred. The polymer may for example be selected from a wide range of thermoplastic and thermosetting polymers as well as structural foams of these materials. Typical materials include polystyrene, polycarbonate, polyamides, polyesters, phenolics, epoxies, vinyl esters and the like. In addition, suitable elastomers such as for example silicones, urethanes, Hypalons, EPDMs and foams thereof may be used. When used as a structural member, it is naturally preferred to employ conventional engineering structural polymers. Typical of such thermoplastic polymers are the ABS resin acrylonitrile-butadiene-styrene copolymer which may be a blend produced from all three monomers or mixtures of copolymers or graft polymers such as styrene and acrylonitrile grafted on polybutadiene. In addition, other high-temperature engineering plastics, such as polysulfone, polyphenylene sulfide, polyether imides, poly(amide-imide) and fluoroplastics may be used. Further, low-cost molding materials, including polyphenylene oxides such as Noryl, may be used.

The electrically insulating polymer may be loaded with any suitable polymeric fibrous material capable of heat conversion to conductive fibrous carbon within the polymer matrix. Typical of such fibrous filler are cellulose (rayon) and petroleum pitch based carbon fibers which are heat-convertible carbonaceous fibers. A particularly preferred carbonaceous fiber or filler is thermally stabilized, polyacrylonitrile fibers which, upon heat conversion, provide electrically-conducting fibers. These fibers are thermally stabilized by heating polyacrylonitrile fibers to temperatures of the order of 300°C in the presence of oxygen and usually under tension for a long period of up to twenty four hours, wherein the polyacrylonitrile is changed from a white to a black fiber while maintaining its electrically insulating characteristics. These thermally stabilized fibers (also known as 'preox fibers') can be made electrically conducting upon subsequent heat treatment to temperatures of the order of 2,000°C in an inert atmosphere.

As used herein, the term 'electrically insulating' is intended to define materials having a resistivity greater than about 10^{14} ohm centimeters, and the term 'electrically conductive' is intended to define materials having a resistivity less than about 10^{9} ohm centimeters. The degree of loading the polymer matrix with the fibers is such that upon the heat conversion of the fibers the converted fibers are in electrical contact with each other, providing an electrically-conducting path in the polymer matrix. Typically, the fibers may be included in the polymer matrix in an amount of from about 5 to 70% by weight of the total filled polymer matrix. Preferably, however, from about 10 to 30% by weight of the polymer matrix is made up of the fibers. Since the cost of the fibers is substantially more than the cost of the polymer, this range generally provides a good balance between cost and filler function in addition to providing the conducting path. At higher fiber loadings, greater reinforcement and strength is achieved in the composite. At lower fiber loadings, there are fewer difficulties in dispersing the fiber in the polymer. If desired, the fibers can have an adhesion promoter such as polyvinyl alcohol, polyvinyl chloride or expoxy monomers coated thereon to enable the polymer in the fluid state when it is heated to adhere readily to the fibers. In addition, other additives such as fiber glass, or flame retardants such as halogenated hydrocarbons, may be added to the polymer matrix for additional reinforcement and flame-retardancy respectively. Typically, the fibers have a length much greater than their diameter, with the length being from 1 to 12 mm and the diameter from 5×10^{-3} to 5×10^{-2} mm. It is important that the fibers be of sufficient length that upon pyrolysis they are capable of bridging the area from the pyrolyzed polymer matrix to the bulk of the unpyrolyzed polymer matrix to give durability to the final product. It is therefore important that the fibers maintain their fibrous nature during the compounding operation that result in a uniform dispersion of fibers throughout the polymer matrix. In addition to the fibers providing the conductive path following heat conversion, they also add structure to the host polymer, acting to strengthen and stiffen it. In some applications compounding and molding techniques, such as two-stage molding, for example, that cause the fibers to preferentially move to the surface, may be preferred.

The filled polymer matrix may be formed into an electrical component by conventional molding or extruding techniques. A particularly preferred technique is injection molding wherein three-dimensional parts may be made in a very short time which do not require any post machining such as drilling or routing. If the electrical component is to be used as a support member, such as a structural frame member or cover, the polymer used should be one of the structural polymers mentioned above. Subsequent to the formation of the part, a portion of the polymer matrix corresponding to the desired conductive path is heated to a temperature sufficient to convert the electrically insulating fibrous filler to an electrically conductive fibrous filler, thereby providing an electrically-conductive path. The requisite heating may be carried out in any suitable manner which generates sufficient thermal excitation in the polymer matrix to convert the electrically insulating fibrous filler to an electrically conductive filler in the desired areas. While other techniques such as electron beam may be used, it

is preferred to use a laser beam directed to a portion of the polymer matrix to pyrolyze the portion by melting the polymer and converting the electrically insulating fibers to electrically conductive fibers to form the conductive path. A laser is a fast efficient tool, and continuous-wave or pulsed lasers may be employed which provide a narrow laser beam exposure of the polymer matrix in a predetermined pattern so that the convertible fibers will selectively absorb the radiation and heat convert preferentially, becoming conductive relative to the host polymer. This is particularly effective with the black thermally stabilized polyacrylonitrile fibers which can more readily absorb the radiation. Any suitable laser may be employed, it being required only that it impinge on the polymer matrix for a sufficient time and with sufficient power to raise the temperature of the fibrous filler to a temperature sufficient to render it electrically conducting. Both argon and carbon dioxide lasers are effective in this regard.

During the pyrolysis, the polymer matrix is heated locally and undergoes a thermal melting and decomposition with the hottest areas decomposing with the potential for some volatile decomposition products cooling upon contact with and then condensing on adjacent areas. There is some molten plastic flow in a narrow area and a narrow groove or trough may be observed in the exposed areas. During the pyrolysis, the fibers are converted to electrically conducting fibers and may be observed in the groove or trough with the heat converted conductive portion of the fiber in the trough and the remaining insulating portion in the unpyrolyzed polymer matrix. As discussed previously, it is important that the fiber fill density be sufficient to ensure a plurality of contact points between fibers to produce a continuous conductive fiber path. The exposure or heat conversion is preferably carried out in an oxygen-free atmosphere since oxygen tends to impede achieving high conductivity, by converting carbon to carbon dioxide gas. The polymer/fiber composition has to be capable of absorbing the laser energy and the product of the absorption must be the necessary rise in temperature to melt or vaporize the polymer and heat convert the fibers. In other words, the fiber-filled polymer matrix must absorb light at the writing or marking wavelength of the laser and result in the necessary rise in temperature.

For example, a test plaque made of ABS resin with 30% by weight of heat-stabilized chopped 'preox' polyacylonitrile fibers when exposed to a 200 watt peak power industrial CO_2 laser used at 20 watts and pulsed unfocused at 200 to 300 pulses/sec, while scanning at about 35mm/sec produced a visbile groove, forming a conductive trace in the plaque having a D.C. volume resistivity of about 20 ohm-cm. This level of conductivity is sufficient for some purposes such as for example in situations where a high series impedence can be tolerated such as a sensor, for example, or in forming a pattern for subsequent electroplating the trace. It is preferred to provide a conductive trace when used as a circuit having a resistivity as low as possible and less than about 10^{-2} ohm-cm.

The conductive paths may be individually created by directing a single laser beam for each path. If it is desired to create a plurality of conductive paths in a single-piece part, a programmable bed or robot may be coupled in unison with the laser. The motion of the robot would align and carry the part under the laser at a predetermined scan rate. Upon completion of the formation of one conductive path, the laser can be shut off, the part indexed and realigned and the laser re-energized and the bed proceed to transport the part under the laser once again. This procedure, however, has the disadvantage of being relatively inefficient and time-consuming and accordingly, if a plurality of conductive paths is desired to be formed in the part, the part can be masked with a mask having a predetermined conductive path pattern and thereafter randomly and/or continuously exposed to the laser thereby pyrolyzing only that portion of the substrate visible through the pattern in the mask. Typically such a mask is made from a material which is known to reflect the energy of the laser used. For example, a copper mask could be used to reflect the energy of the carbon dioxide laser without effect upon the copper. This procedure has the advantage in that the pattern size, shape and number of conductive paths are controlled by the mask and not by the programmable bed. Accordingly, higher line densities, better line resolution, as well as improved pattern repeatability, are achievable. Furthermore, process efficiency can be enhanced with the use of wide laser beams to pyrolyze many traces by a single pass of the part under the laser.

While the above-described process is effective in producing paths that are sufficiently conducting to support a current flow or voltage, there may be situations in which metallic conductivity is desired on particular parts or particular portions thereof. Accordingly, conventional electroless or electroplating techniques and materials may be used to provide metallic conductivity to the conductive paths. Typical metals that may be employed include copper, nickel, gold, silver, tin, lead and platinum. Metallic plating also has the advantage in that it ensures reliability of the mechanical interconnects between piece parts. In the plating process the conductive fibers are not only sites for plating but also promote adhesion of the plating to the substrates. In this process the groove formed also helps mechanical bonding.

According to the present invention, the laser beam is moved relative to the piece in which it is desired to create a conductive path or a pattern of conductive paths. This may be readily accomplished by holding the laser beam or the work piece stationary, while the other is moved relative to the stationary item, or by simultaneously moving both the laser and work piece in a controlled programmed manner. By controlling the relative motion of the laser beam relative to the piece, conductive paths or patterns of conductive paths may be readily created in three-dimensional objects or shapes as well as two-dimensional surfaces.

Attention is directed to Figure 3 which schematically illustrates a manner in which a plurality of conductive paths representing circuit patterns can be prepared in a part.

The part 40 is secured to table 42 which is rotatably mounted about the center axis 43 of a motor shaft (not

shown) in the motor box 44. In addition, the table is movable in the XY plane by movement of worm gear 46 by another motor (not shown) in the motor box 44. The laser scanning carriage 48 has three lasers 50, 52, 54, one directed in each direction with the carriage movable vertically by worm gear 56 and motor 58 and horizontally by worm gear 60 and motor 62. The movement of the table 42 and the scanning carriage 48 is controlled by a programmable controller 64 to form the preselected pattern of conductive traces in the part 40. If desired, a mask 66 having a predetermined pattern may be placed over at least a portion of the part so that the part may be continuously exposed to the laser. If desired the entire assembly may be placed in an inert atmosphere or a vacuum chamber. Alternatively or in addition an exhaust hose may be placed adjacent the part being marked to remove any noxious materials produced by pyrolysis.

It will be appreciated that Figure 3 is merely representative of one manner and device that may be used to form the pattern of conductive traces, and that other apparatus and techniques can be used. For example, the laser may be stationary and used with rotating or translating mirrors programmed to cause the beam to scan the part in one, two or three directions.

Accordingly, in fabricating a machine such as electrostatographic reproducing apparatus having a plurality of electrical components, the techniques described above can be used to provide the necessary circuitry in situ in the individual parts as frames, covers, support members, etc. so that upon assembly of the final product, the individual parts can be put in their proper position and the use of individual wires and wiring harnesses substantially minimized if not eliminated. The electrical contacts between the conductive paths on the individual parts may be made with those conventional techniques available to the printed circuit board industry. Particularly-effective techniques include the use of electrically-conductive lands or pads as part of the circuit proper in the individual parts which are placed in contact as a result of their final positioning in the main machine, thereby completing the circuits.

Referring now to Figures 4A, 4B and 5A and 5B, in Figure 4A a structural component 26 such as a subchassis may be made from an insulating structural polymer matrix 27 filled with heat-convertible fibers which has a conductive path 28 formed therein. Alternatively, the polymer matrix may be present as an adherent coating 36 on a support member 38 as illustrated in Figure 4B. The enlarged view of Figure 5A illustrates a groove 30 formed in the polymer matrix by melting and some decomposition of the polymer locally in response to exposure to the laser beam. The troughs or grooves so formed may be of the order of 0.1 to 5.0 millimeters wide and from about 0.2 to 2.0 millimeters deep. Contained within the trough are conductive fibers 32 which have been heat converted by exposure to the laser beam. As previously discussed, preferably this exposure or conversion took place in an oxygen-free atmosphere. While the portion 32 of the individual fibers in the trough has been heat converted, it should be noted that a portion 34 of the individual fibers extending into the polymer matrix has not been heat converted and serves to anchor the fibers in place in the polymer matrix.

Alternatively, as seen in Figure 5B, the groove 30 may have an adherent metallic layer 36 plated thereon by conventional techniques to achieve metallic conductivity.

EXAMPLES 1-7

A carbon dioxide laser with a beam focused to a 200 µm spot having an output power of 1.8 watts was used to produce traces in a series of 50 x 50 mm injection-molded test plaques made of polyphenylene oxide, General Electric Noryl resin, with 20% by weight of the total weight being heat-stabilized preox polyacrylonitrile fibers chopped to lengths of about 6 mm with diameters of about 10 µm . The test plaques were placed on a programmable sample table in a vacuum chamber with a transparent window for passage of the continuous wave laser beam and the following traces were made while argon flowed continuously over the samples in the chamber at a pressure of 800 Nm^{-2}.

Example Trace	Power	Scan Rate mm/sec	Scans	Trace Width mm
1	1.8W	.3	1	1.12-1.52
2	1.8W	.3	2	1.52-1.63
3	1.8W	.6	1	1.42-1.52
4	1.8W	.6	2	1.52-1.63
5	1.8W	1.0	2	0.91-1.02
6	1.8W	2.0	2	0.71-0.81
7	1.8W	3.0	2	0.61-0.71

The number of scans is the number of replicate scans in the same trace to try to achieve better uniformity. The resistivity for all traces was determined to be about 0.8 ohm.cm.

EXAMPLE 8

The plaque of Example 4 was placed in a commercial gold electroplating solution (Orotemps -24, a neutral gold plating solution available from Technic Inc., Providence, R1), with 2.4 volts current limited to 1 to 5 milliamps/centimeter for 8 to 12 minutes, after which it was removed from the bath, rinsed in deionized water, and dried. Visual observation confirmed that gold had been electroplated in the trace area. The DC resistance was determined to be near zero with a conventional multimeter.

EXAMPLE 9

Ten parts by weight of the composition which the plaques are made of in Examples 1-7 was mixed with 90 parts of weight of toluence and milled in a roll mill for 48 hours to dissolve the polymer. The resulting dispersion was applied with a brush to the surface of a test plaque of unfilled Noryl molded structural foam to a thickness of about 25 µm. Following drying of the coated plaque, it was exposed to the laser beam in the manner of Examples 1-7 with a conductive trace being formed. The trace carried into the substrate and the resultant conductive path was formed by the fibers originally in the coating residing eventually in the substrate.

EXAMPLE 10

A carbon dioxide laser with a beam focused to a 200 µm spot having an output power of 3 watts was used to produce a trace in a 50 x 50 mm injection molded test plaque made from General Electric Ultem resin, polyetherimide, filled with 20% by weight of the total weight of heat stabilized preox polyacrylonitrile fibers chopped to a length of about 6 mm with a diameter of about 10 µm . The plaque was placed on a programmable sample table in a vacuum chamber with argon continuously flowing over the sample at a pressure of kNm^{-2} while a trace was made in the plaque with a single scan of the laser at a scan rate of 1 mm/sec. A conductive trace about 0.2 cm wide and 0.4 cm deep with a resisitivity of about 2.1×10^{-3} ohm.cm was produced.

EXAMPLE 11

The procedure of example 10 was repeated except that the plaque was made from General Electric Noryl resin, polyphenylene oxide, filled with 20% by weight of the total weight of the same heat stabilized preox polyacrylonitrile fibers and the scanning rate was 2 mm/sec. A trace having about the same geometry and a resistivity of about 7.4×10^{-3} ohm.cm was obtained.

Accordingly, the present invention provides an economical alternative to conventional wiring and wire harness construction. It has the advantage of being able to integrate electrical or mechanical functions in the same part while at the same time facilitating automated manufacture of individual parts and automated assembly of such parts in a machine configuration. By integrating machine and component circuitry into mechanical or structural members, substantial cost savings may be achieved in manufacturing and assembly labor, inventory costs in that individual wires, pins, connectors, etc. can be eliminated. For example, a typical conventional wiring harness of say 70 wires and connectors can be reduced to but a single part. Furthermore, since the parts are subject to automated manufacturing techniques, substantial reduction in manufacturing and assembly error as a result of human involvement may be avoided. In addition, since the technique according to the present invention is capable of automated mass production, substantial cost savings may be passed on to the ultimate consumer.

While the invention has been generally illustrated with the conductive trace formed in the surface layer, it will be appreciated that the surface layer may be subsequently coated or the layer in which the conductive path is formed may be sandwiched between two other layers and be exposed to the laser beam through one of the layers which transmits light of the writing wavelength. Furthermore, while the invention has been described with specific reference to electrostatographic copier and printer machines, it will be appreciated it has application to a large array of machines with electrical components.

Claims

1. An electrical component comprising a matrix (27) of an electrically-insulating polymer filled with fibres (34) of an electrically-insulating material capable of being converted by heat into electroconductive fibres, the matrix having in it at least one electroconductive path (28) formed by the on-site application of heat to the fibrous material.

2. The electrical component of claim 1, wherein the polymer matrix is an adherent surface layer on a base support member (38).

3. The electrical component of claim 1 or 2, wherein the fibres are of heat-convertible, carbonaceous material, and the conductive path comprises carbonized fibers.

4. The electrical component of claim 3, wherein the material is thermally-stabilized polyacrylonitrile resin.

5. The electrical component of any preceding claim, containing from 5 to 70% by weight of fibrous filler.

6. The electrical component of claim 5, containing from 10 to 30% by weight of fibrous filler.

7. The electrical component of any preceding claim, wherein the polymer matrix has a resistivity greater than about 10^{14} ohm.cm, and the electrically-conductive path has a resistivity less than about 10^{9} ohm.cm.

8. The electrical component of any preceding claim, wherein at least one electrically-conductive path comprises a narrow groove formed by laser pyrolysis of a portion of the filled polymer matrix which was effective to melt the polymer locally and to convert the electrically-insulating fibers into their conductive form.

9. The electrical component of claim 8, wherein the narrow groove has an adherent continuous coating (36) of a conductive metal plated thereon.

10. The electrical component of any preceding claim, comprising a plurality of conductive paths.

11. A method of forming at least one electrically-conductive path in a matrix of an electrically-insulating polymer filled with electrically-insulating fibrous filler material capable of being converted by heat into electrically-conducting fibres, comprising heating the portion of the matrix corresponding to a desired electroconductive path to a temperature sufficient to convert the filler material into conductive fibres which form the desired electrically-conductive path through the matrix.

12. A machine including at least one electrical component as claimed in any preceding claim.

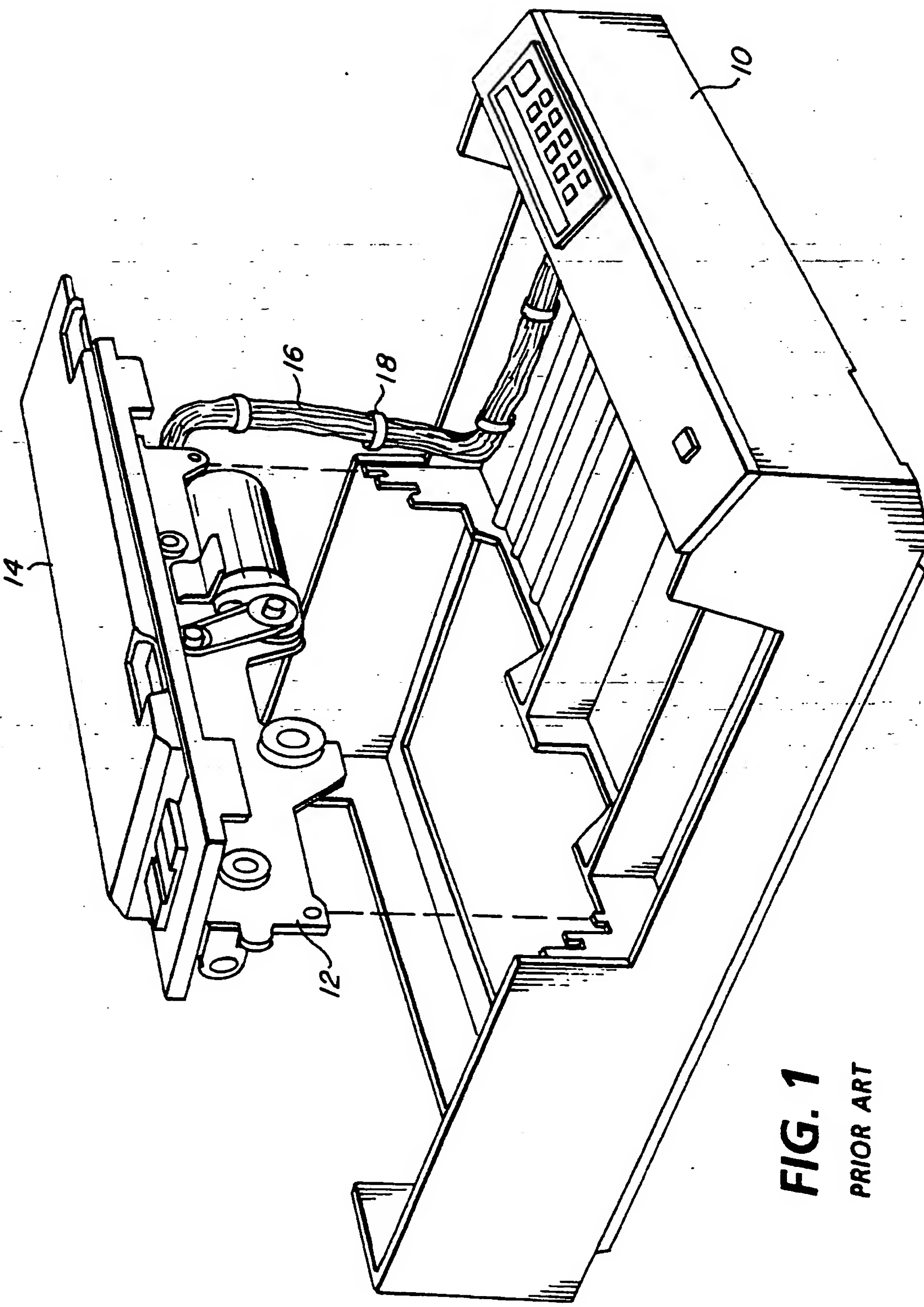

FIG. 1
PRIOR ART

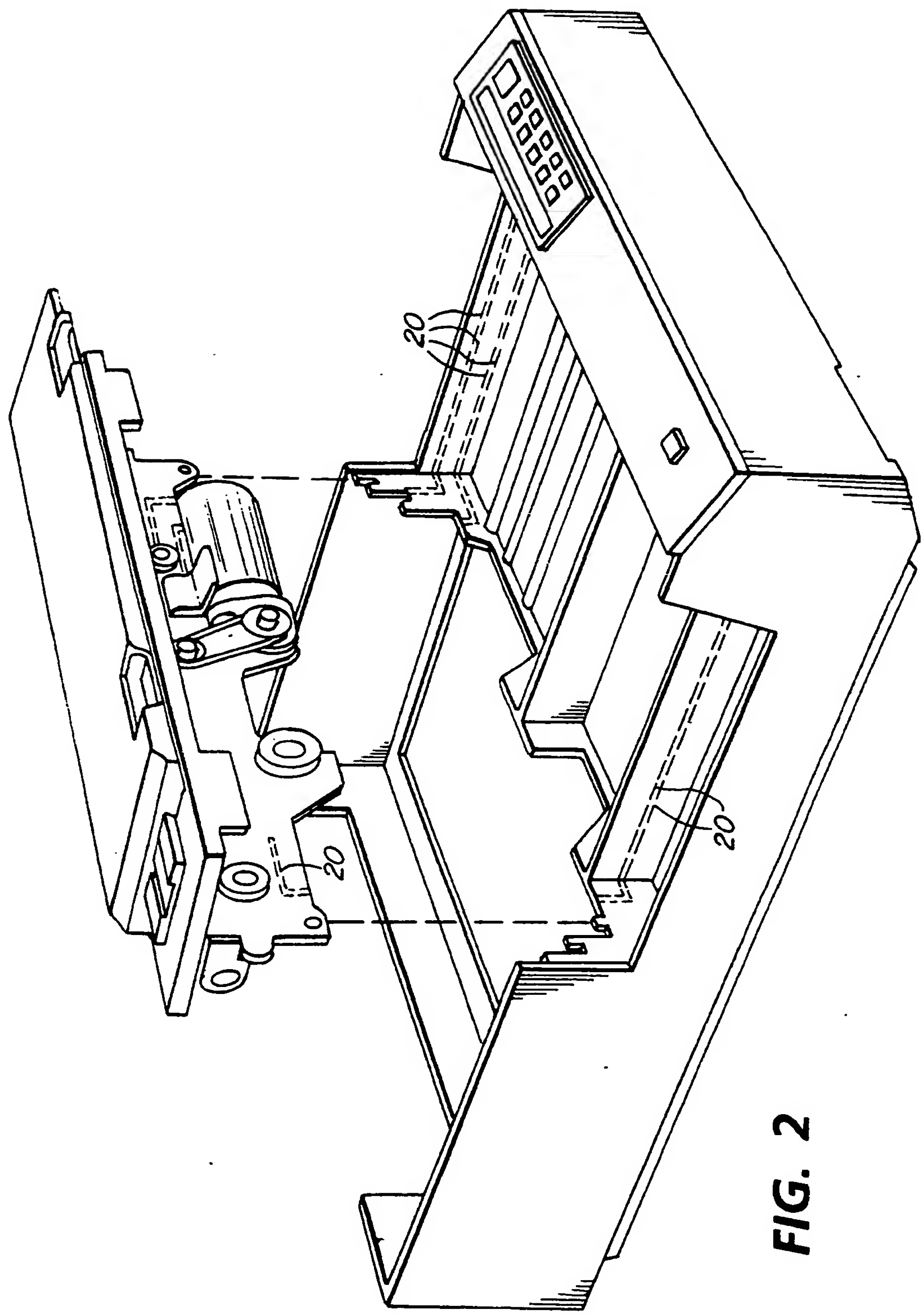

FIG. 2

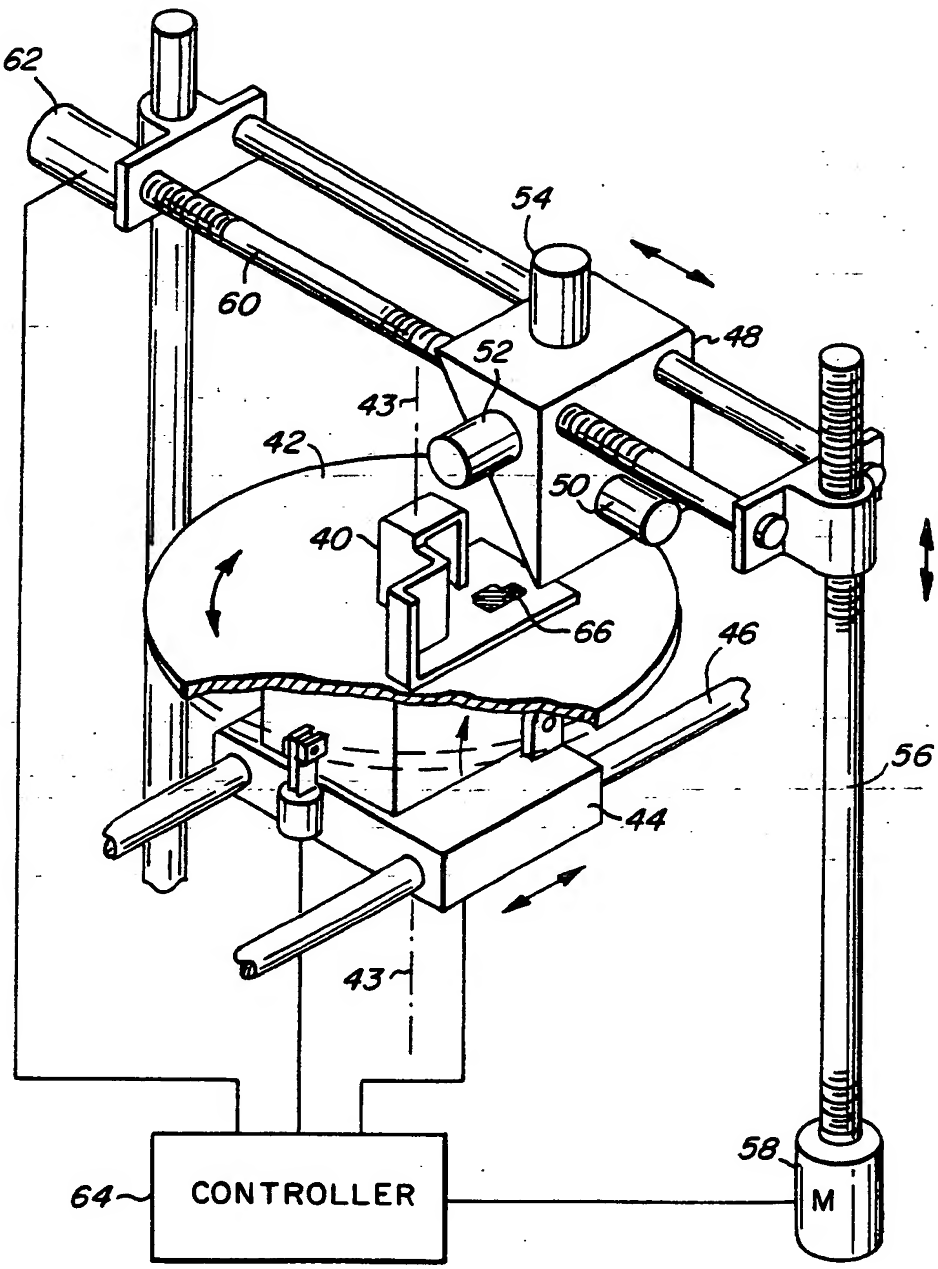

FIG. 3

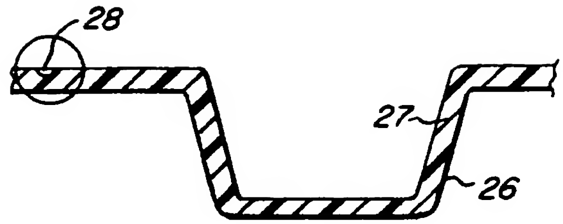

FIG. 4A

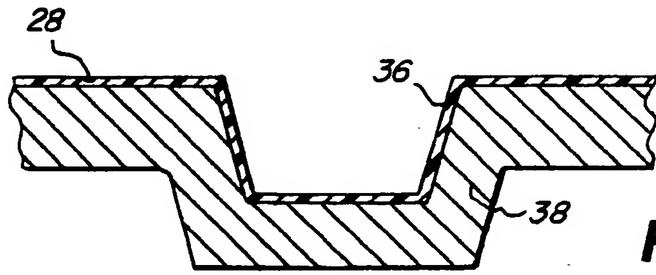

FIG. 4B

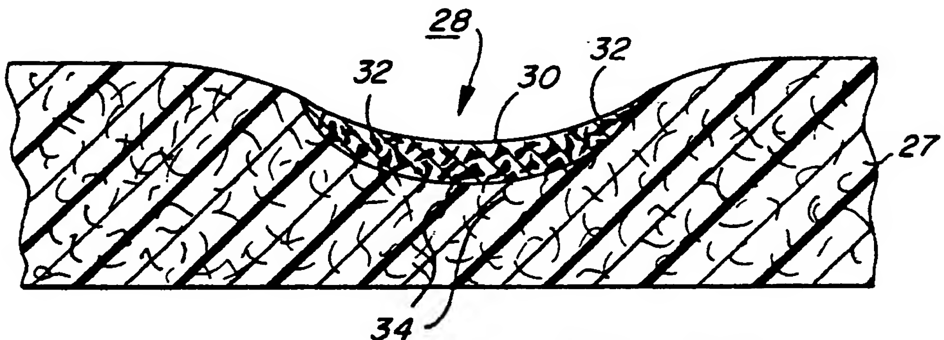

FIG. 5A

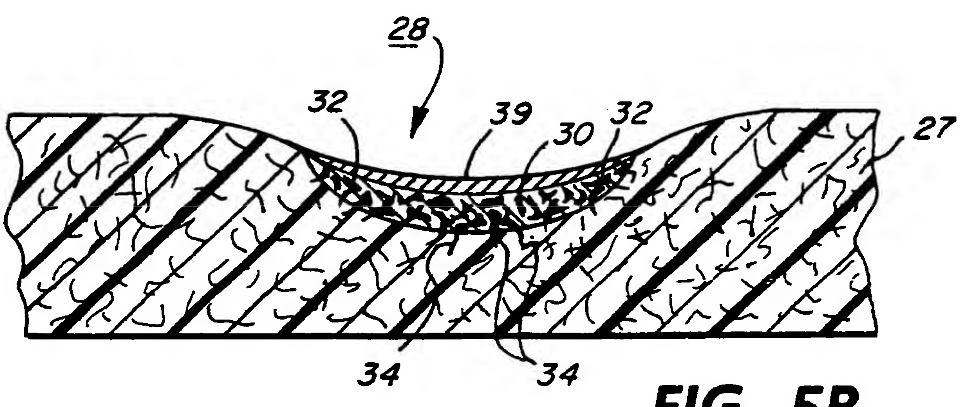

FIG. 5B

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